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(19) (CA) **CANADIAN PATENT** (12)

(54) Method of Removing Substances from Fossil Derived,  
Hydrocarbon Liquids

✓(72) Kutowy, Oleg;  
Tweddle, Thomas A.;  
Harlett, John D.,  
Canada

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This invention relates to a method of removing dissolved contaminants with relatively high molecular weights and inorganic substances from fossil derived, hydrocarbon liquids.

5           It has already been proposed in United States Patent Number 4,093,540, dated June 6, 1978, "Purification Process", A.K.S. Gupta, to refine dilute glyceride oil compositions by contacting them, in solution in an organic solvent with a semi-permeable (e.g. poly-sulphone or polyacrylonitrile) membrane to separate constituents of  
10 different molecular weights into retentate and permeate fractions. The removal of, say, phosphatides (lecithins) from, say, a hexane solution of crude vegetable oil by the Gupta process is possible because lecithins, when dissolved in hexane, form molecular aggregates known as micelles with a molecular weight as high as 200,000.

15           While the Gupta process has been found useful for separating these high molecular weight aggregates, it is not possible to form such high molecular weight aggregates with hexane from high molecular weight fractions of, or inorganic substances, present therein as  
20 solutions and suspensions, from fossil derived hydrocarbon liquids, and so the Gupta process is not useful as a separation process in this instance, unless, as taught by Gupta, these substances (e.g. bitumen, calcium or magnesium) are present chemically associated with the phospholipids which is never the case. This is borne out by the fact  
25 that Gupta teaches that copper is not removed by his process.

          There is a need for a process where high molecular weight fractions of organic or inorganic substances, present as solutions



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1 and suspensions and not chemically associated with phospholipids,  
are removed from fossil derived hydrocarbon liquids.

According to the present invention there is provided a method  
5 of removing substances from fossil derived, hydrocarbon liquid  
comprising, passing the fossil derived hydrocarbon liquid as a feed  
containing at least one substance selected from the group consisting of  
higher molecular fractions thereof and inorganic substances and having  
a viscosity of less than about 600 centipoise, across a high pressure  
10 side of a microporous membrane, at pressure differential in the range  
of about one atmosphere to about 100 atmospheres (i.e. 0.1 to 10.0  
MPa), at least an outer layer of the membrane, on the high pressure  
side thereof, being of at least one lyophilic, hydrocarbon liquid  
stable, organic, polymeric material, and having a microporous structure  
15 that provides the said at least an outer layer with a molecular weight  
cut off of less than about 20,000, when measured in a. aqueous medium,  
and less than 4,000, when measured in oil, so that oil depleted in the  
said at least one substance permeates the membrane leaving liquid  
hydrocarbon enriched in the said at least one substance as a retentate  
20 on the high pressure side of the membrane.

The hydrocarbon liquid feed may contain asphaltenes and the  
permeate may be essentially asphaltene free.

25 The viscosity of the hydrocarbon liquid feed may be reduced  
to less than about the said 600 centipoise by heating the hydrocarbon

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liquid. This will ease the processability and reduce the pressure drop of the hydrocarbon liquid feed on the retentate side of the membrane. The viscosity of the feed hydrocarbon liquid may also be reduced to less than about the said 600 centipoise by diluting the hydrocarbon liquid  
5 feed with a solvent therefor.

Separated solids in the retentate may be separated from the remaining retentate, and then the remaining retentate recirculated to the membrane for further separation.

The retentate may be enriched with at least one inorganic  
10 substance selected from the group consisting of nickel, vanadium, chromium, copper, aluminum, boron, titanium, zinc, lead, iron, nitrogen, silicon, phosphorus, magnesium, calcium and sulphur present in the hydrocarbon liquid.

Preferably the viscosity of the hydrocarbon liquid permeate is  
15 less than about 50 percent of that of the hydrocarbon liquid feed.

In some embodiments of the present invention the said outer layer is of at least one material selected from the group consisting of polysulfones, polyacrylonitriles, polyamide and polyvinylidene fluoride.

In other embodiments of the present invention the hydrocarbon  
20 liquid feed is passed across the retentate side of the membrane with the hydrocarbon liquid feed having a viscosity of less than about 400 centipoise, and the microporous structure of the said at least outer layer provides that layer with a molecular weight cut off of less than about 10,000 in an aqueous medium. This is particularly useful for  
25 removing, for example, asphaltenes from tar sand bitumen in addition to removing inorganic substances therefrom.

In the accompanying drawings which are provided for a better understanding of the present invention:

Figure 1 shows a flow diagram of apparatus used to verify the present invention,

5        Figure 2 is a graph of the molecular weight distribution of a light oil before and after the separation of inorganic substances therefrom, and

      Figure 3 is a graph of the molecular weight distribution of a heavy oil before and after the separation of inorganic substances  
10        therefrom.

In Figure 1, there is shown a tank 1, containing fossil derived, aromatics and aliphatics containing, hydrocarbon liquid 2, a stirrer 4 in the hydrocarbon liquid 2, a tank 6 containing a solvent 8 for the hydrocarbon liquid 2, pumps 10 and 12, a heat exchanger 14, a membrane  
15        separating device 16 having a microporous membrane 18, a tank 20 containing retentate 22, a centrifugal separator 24, pumps 26, 28 and valves 30 to 33.

At least an outer layer 34 on the high pressure side of the membrane 18 is of at least one lyophilic, hydrocarbon liquid stable,  
20        organic, polymeric material, and has a microporous structure that provides that said at least an outer layer with a molecular weight cut off of less than about 20,000 when measured in an aqueous medium. One method of providing such a membrane 18 is described and claimed in United States Patent No. 4,451,424, for casting polysulfone membranes, and other  
25        methods of producing such membranes in other materials are well known to persons skilled in the art.

In operation, hydrocarbon liquid 2, together with a solvent 8, such as naphtha, mixed therewith by stirrer 4, if it is necessary to reduce the viscosity of the hydrocarbon liquid 2 in this manner, is pumped by the pump 12 through the heat exchanger 14 to provide a pressure differential in the range one to 100 atmospheres at the membrane 18 of the membrane separating device 16. The heat exchanger 14 may heat the hydrocarbon liquid 2 to, in conjunction with the solvent 8, or in place thereof, reduce the viscosity of hydrocarbon liquid 2 if this is necessary.

10 In operation, the hydrocarbon liquid 2 containing e.g. at least one inorganic substance is pumped by pump 12 through the heat exchanger into the separating device 16, to the side of the membrane 18 having outer layer 34. As previously stated, if necessary, the viscosity of the hydrocarbon liquid 2 can be reduced to less than about 600 centipoise by mixing the solvent 8 with the hydrocarbon liquid 12 using the stirrer 4. 15 The viscosity of the hydrocarbon liquid 2 can also, if necessary, be reduced to less than about 600 centipoise by heating the hydrocarbon liquid using the heat exchanger 14 alone or in combination with the addition of solvent 8 thereto.

20 It is necessary for the viscosity of the hydrocarbon liquid to be reduced to less than about 600 centipoise in order that the hydrocarbon liquid can be pumped across the outer layer 34 of the membrane 18 to pass through the membrane at a pressure differential in the range of one to 100 atmospheres and in order that the membrane 18 will not become 25 blinded by the hydrocarbon liquid.

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The hydrocarbon liquid is forced through the membrane 18 leaving behind a retentate enriched with the inorganic substance or substances. The retentate flows across the membrane and is collected in the tank 20. If desired, retentate 22 may be pumped by pump 26 from the tank 20 to the centrifugal separator 24 where solid substances are removed from the retentate and returned to the tank 20. The retentate with solid substances removed therefrom is pumped by the pump 28 to the tank 1 to be processed once more.

The following tables give the results of tests carried out to verify the present invention using the apparatus shown in Figure 1.

Each table gives the results of different tests carried out for the removal of inorganic substances for a particular fossil derived, hydrocarbon liquid using similar or different membranes in each test in a table.

In the following Table 1, new and used diesel lubricating oil was passed at a pressure of  $1.0 \pm 0.1$  Bar at  $60^\circ\text{C}$  through the membranes specified at the particular fluxes given.

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TABLE I

Spent diesel lubrication oil (SAE 70)

Inorganic Substances Present (PPM)													
Test No	Membrane	Permeate (Inorganic Substances)										Visc.	Flux
		Al	Cu	Fe	Pb	Si	Zn	Ca	P				
New Oil	Used Oil	2	1	1	1	2	564	1373	537			30	•
		4-9	7-20	43	1	10	581	1629	651			30-37	
1	70-T	1	7	1	0.8	2	70	53	225			20	7.1
2	85-T	1	3	1	1	4	72	55	185			24	3.6
3	PI	1	2	1	1	5	192		305			28	

a Kg/m<sup>2</sup>/day

PPM is in milligrams per litre.

70-T is a flat polysulfone membrane which separates polyethylene glycol of molecular weight 6,000 to 702 as defined by concentration in feed-concentration in permeate and 85-T is a flat polysulfone membrane which

separates polyethylene glycerol of molecular weight 6000 to 852 as defined above, indicating that the molecular weight cut off of the membranes is around 10,000 and 7,000 respectively. In both 70-T and 85-T the polysulfone membrane was cast on a sup. of a spun bonded polyethylene paper marketed under the trade mark TYVEK by Du Pont, Wilmington, Delaware, U.S.A. PI was a polyimide polymer composite marketed as polyimide 8010 by the Upjohn Co. Ltd., Kalamazoo, Michigan, U.S.A.



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The following Tables II to XII give the results of tests for different fossil derived, free flowing, hydrocarbon liquids using flat polysulfone membranes on polyester supports.

Where the membrane numbers are followed by U, such as 2U, this indicates that these membranes were made from polysulfone marketed under trade name UDEL 3500 by Union Carbide Corporation.

Where the membrane numbers are followed by V, such as 3V, this indicates that these membranes were made from polysulfone marketed under the trade mark VICTREX by Imperial Chemical Industries, London, England.

In the Tables the separation results given for chromium and vanadium were measured using a method that was unreliable below 2 ppm and so these results are given merely to show that separation of chromium and vanadium occurred.

In the following Table II the feed was Venezuela crude oil, fed at a flow rate of 0.192 Kg/second, and at a temperature of 30°C. The feed pressure was between 2.0 MPa and 2.5 MPa. The volume of crude oil used in each test was 9.0 liters having a mean viscosity at 30°C of 10.0 cFS.

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TABLE II

MEMBRANE	INITIAL FEED	MEMBRANES IN SERIES FLOW					FINAL FEED
		1U	2V	3U	4V		
PRESSURE, MPA		2.45	2.27	2.18	2.09		
FLUX, KG/M <sup>2</sup> .D		30.20	31.40	120.50	77.40		
VISCOSITY, CPS VARIATION, %	13.54	3.32 77.50	3.49 76.30	3.44 76.70	4.13 72.00	15.95	
SULPHUR, % SEPARATION, %	1.16	0.61 46.50	0.64 43.90	0.62 45.60	0.67 41.20	1.12	
VANADIUM, PPM SEPARATION, %	102.00	3.00 97.10	3.00 97.10	3.00 97.10	5.70 94.50	6.00	
NICKEL, PPM SEPARATION, %	11.00	0.70 93.60	0.70 93.60	0.70 93.60	0.70 93.60	11.00	
CHROMIUM, PPM SEPARATION, %	2.40	0.60 70.70	0.60 70.70	0.60 70.70	0.60 70.70	1.70	
NITROGEN, G/L SEPARATION, %	8.04	2.04 74.7		1.91 76.2	2.31 71.3	8.04	

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In the following Table III the feed was the Venezuelan crude oil retentate from the test of the same designation in Table II, which was the remaining concentrated 60% by volume of the feed for Table II.

In Table III the flow rate of the feed pressure for each test was 0.065 Kg/second, at a temperature of 37°C. The feed pressure was between 2.0 MPa and 2.5 MPa. The volume of oil used in each test was 5.0 liters having a means viscosity at 37°C of 25.5 CPS.

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TABLE III

MEMBRANE	INITIAL FEED	MEMBRANES IN SERIES FLOW				
		1U	2V	3U	4V	FINAL FEED
PRESSURE, MPA		2.45	2.27	2.18	2.09	
FLUX, KG/MP.D		18.40	20.60	66.80	41.80	
VISCOSITY, CPS	37.00	4.93	5.36	5.23	6.27	55.68
VARIATION, %		89.40	88.40	88.70	86.50	
SULPHUR, %	1.34	0.71	0.73	0.71	0.78	1.39
SEPARATION, %		48.00	46.50	48.00	42.90	
VANADIUM, PPM	143.00	3.00	3.00	3.00	10.00	157.00
SEPARATION, %		98.00	98.00	98.00	93.30	
NICKEL, PPM	15.00	0.70	0.70	0.70	1.20	16.00
SEPARATION, %		95.50	95.50	95.50	92.30	
*CHROMIUM, PPM	2.60	0.60	0.60	0.60	0.60	2.60
NITROGEN, G/L	10.41	ALL > 77% SEPARATION	NO TEST	2.56	3.04	10.41
SEPARATION, %		2.51		75.6	70.8	
		75.9				

\*Chromium separation should be above 90% but the results obtained used a measuring method which was unreliable below 2ppm and so results are given merely to show that chromium separation occurred.

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In the following Table IV the feed was Texas crude oil, fed at a flow rate of 0.270 Kg/second, and at a temperature of 20°C. The feed pressure for each test was between 2.0 MPa and 2.5 MPa. The volume of crude oil used in each test was 5.0 liters having a mean viscosity at 20°C of 5.1 CPS.

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TABLE IV

MEMBRANE	MEMBRANES IN SERIES FLOW										
	INITIAL FEED	1U	2V	3V	4V	5V	6U	7U	8V	9V	FINAL FEED
PRESSURE, MPa		2.45	2.36	3.43	2.27	2.23	2.18	2.14	2.09	2.05	0.00
FLOWRATE, MG/S		29.18	5.50	4.43	15.52	48.11	119.60	109.20	252.60	162.22	0.00
FLUX, KG/M <sup>2</sup> .D		158.6	29.9	24.1	86.30	251.40	649.90	593.41	318.30	881.80	0.00
VISCOSITY, CPS	4.78	3.81	3.51	3.24	0.00	4.04	4.12	5.02	4.63	4.64	5.30
VARIATION, %		24.4	30.4	35.7	100.00	19.8	18.30	20.20	8.10	7.92	0.00
SULPHUR, %	0.20	0.18	0.17	0.16	0.17	0.18	0.18	0.17	0.19	0.19	0.19
SEPARATION, %		7.70	12.80	17.90	12.80	7.70	7.70	7.70	2.60	2.56	0.19
NITROGEN, G/L	3.42	2.34	2.31	-	-	-	2.36	-	2.66	-	3.42
SEPARATION, %		31.60	32.3				30.90		22.00		

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In the following Table V the feed was crude oil from Leduc,  
Alberta, Canada, fed at a flow rate of 0.264 Kg/second, and at a  
temperature of 24°C. The feed pressure was between 2.0 MPa and 2.5 MPa.  
The volume of crude oil used in each test was 9.0 liters having a mean  
5 viscosity at 24°C of 56.5 CPS.

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TABLE V

PARAMETER	GENERATORS IN SERIES FLOW									
	INITIAL FIELD	1U	2V	3V	4V	5V	6U	7U	8V	9V
PRESSURE, MPA		2.45	2.36	2.32	2.27	2.23	2.18	2.14	2.09	2.05
FLOWRATE, M <sup>3</sup> /S		7.92	2.03	1.44	7.44	14.35	32.23	30.37	16.29	11.01
FLUX, KG/M <sup>2</sup> .D		43.00	11.00	7.80	40.40	78.00	175.10	165.00	88.50	59.80
VISCOSITY, CPO VARIATION, %	60.25	2.46	2.75	2.87	3.25	2.53	2.54	2.56	2.77	2.68
		96.10	95.60	95.50	94.60	96.00	95.90	95.60	95.60	95.75
SULPHUR, % SEPARATION, %	0.22	0.15	0.14	0.18	0.15	0.15	0.14	0.15	0.16	0.15
		33.30	28.90	20.00	33.30	33.30	37.80	33.30	28.90	33.33
VANADIUM, PPM	1.20	0.60	1.00	1.10	0.60	0.60	0.60	0.60	0.60	0.60
NICKEL, PPM SEPARATION, %	1.30	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
		63.00	63.00	63.00	63.00	63.00	63.00	63.00	63.00	62.96
NITROGEN, G/L SEPARATION, %	4.27 0.00	1.53 64.10	1.83 57.10				1.51 64.70		1.51 62.40	
										4.27



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In the following Table VI the feed was from the Leduc crude oil retentate from the test of the same designation in Table V, which was the remaining concentrated 50% by volume of the feed from Table V.

In Table VI, the flow rate of the feed for each test was 0.129 Kg/second, and at a temperature of 24°C. The feed pressure was between 2.0 MPa and 2.5 MPa. The volume of oil used in each test was 4.5 liters having a mean viscosity at 24°C of 16.5 CPS.

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TABLE VI

MEMBRANE	MEMBRANES IN SERIES FLOW										
	INITIAL FEED	1U	2V	3V	4V	5V	6U	7U	8V	9V	FINAL FEED
PRESSURE, MPA		2.45	2.34	2.32	2.27	2.23	2.18	2.14	2.09	2.05	
FLUX, KG/M <sup>2</sup> .D		21.30	6.20	4.80	22.30	39.50	83.20	75.00	41.70	27.80	
VISCOSITY, CPS	19.67	3.15	4.07	4.43	3.21	3.43	3.31	3.38	3.62	3.67	16.25
VARIATION, %		82.50	77.30	75.30	82.10	80.90	81.60	81.20	79.80	79.57	
SULPHUR, %	0.29	0.18	0.19	0.20	0.18	0.18	0.18	0.18	0.19	0.19	0.30
SEPARATION, %		39.00	35.60	32.20	39.00	39.00	39.00	39.00	35.60	35.59	
VANADIUM, PPM	2.30	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
NICKEL, PPM	2.40	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	2.60
SEPARATION, %		80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	
NITROGEN, G/L	6.58	2.01	2.59				2.26		2.64		6.58
SEPARATION, %		69.50	60.70				65.60		59.90		

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In the following Table VII the feed was that known as Mydale  
crude oil from Venezuela , fed at a flow rate of 0.110 Kg/second, and at  
a temperature of 50°C. The feed pressure was between 2.0 MPa and 2.5  
MPa. The volume of crude oil used in each test was 9.0 liters having a  
5 mean viscosity at 50°C of 19.5 CPS.

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TABLE VII

MEMBRANE	MEMBRANES IN SERIES FLOW										
	INITIAL FEED	1U	2V	3V	4V	5V	6U	7U	8V	9V	FINAL FEED
PRESSURE, MPA		2.45	2.34	2.32	2.27	2.23	2.18	2.14	2.09	2.05	
FLUX, KG/M <sup>2</sup> .D		56.20	15.10	11.90	56.20	83.00	151.60	127.10	90.00	67.20	
VISCOSITY, CPS	50.00	4.51	5.19	6.30	5.08	5.18	5.34	5.85	5.73	6.60	53.00
VARIATION, %		91.20	89.90	87.80	90.10	89.90	89.60	88.60	88.90	87.18	
SULPHUR, %	2.29	1.19	1.17	1.10	1.20	1.19	1.17	1.26	1.26	1.32	2.22
SEPARATION, %		47.20	48.10	51.20	46.80	47.20	48.10	45.00	44.10	41.46	
VANADIUM, PPM	45.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.30	4.70	47.00
SEPARATION, %		95.70	95.70	95.70	95.70	95.70	95.70	95.70	95.00	89.78	
NICKEL, PPM	17.00	0.40	0.40	0.50	0.60	0.50	0.40	0.60	1.10	2.00	18.00
SEPARATION, %		97.70	97.70	97.10	96.60	97.10	97.70	96.60	93.70	88.57	
NITROGEN, G/L	10.83	2.76	2.64				2.66		2.84		10.83
SEPARATION, %		74.50	75.60				75.40		73.80		

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Referring now to Figure 2, there is shown a graph of the molecular weight distribution of the test designated 6U in Table VII, obtained by a high performance liquid chromatograph.

In Figure 2 molecular weight M is plotted against elution volume V, ----- is for the feed which had a weight averaged molecular weight of 576, and ——— is for the permeate which had a weight averaged molecular weight of 320.

In the following Table VIII, the feed was the Mydal crude oil retentate from the test of the same designation in Table VII, which was the remaining concentrated 40% by volume of the feed for Table VII.

In Table VIII the flow rate of the feed for each test was 0.042 Kg/second, at a temperature of 60°C. The feed pressure was between 2.0 MPa and 3.5 MPa. The volume of oil used in each test was 4.0 liters having a mean viscosity at 60°C of 98.7 CPS.

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TABLE VIII

MEMBRANE	MEMBRANES IN SERIES FLOW										
	INITIAL FEED	1U	2V	3V	4V	5V	6U	7U	8V	9V	FINAL FEED
PRESSURE, MPA		3.36	3.09	2.95	2.82	2.68	2.55	2.41	2.27	2.14	
FLUX, KG/M <sup>2</sup> .D		40.60	9.90	7.90	32.00	39.70	73.50	55.80	42.10	35.10	
VISCOSITY, CFS VARIATION, %	673.00	7.61 99.20	9.94 99.00	9.78 99.00	9.87 99.00	10.26 98.90	10.74 98.90	11.91 98.80	13.49 98.60	17.61 98.18	262.00
SULPHUR, % SEPARATION, %	2.86	1.35 49.30	1.44 46.00	1.40 47.50	1.42 46.70	1.45 45.60	1.41 47.10	1.47 44.80	1.53 41.80	1.68 36.96	2.47
VANADIUM, PPM SEPARATION, %	68.00	2.10 97.00	2.30 96.70	2.90 95.90	2.00 97.10	2.60 96.30	2.40 96.60	3.30 95.30	5.60 92.00	15.00 78.57	72.00
NICKEL, PPM SEPARATION, %	25.00	0.80 96.90	1.00 96.20	1.00 96.20	0.90 96.50	0.90 96.50	0.90 96.50	1.40 94.60	2.20 91.50	6.10 76.54	27.00
NITROGEN, G/L SEPARATION, %	15.12	2.81 81.40	3.29 78.20				3.09 79.60		4.04 73.30		15.12

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In the following Table IX the feed was that known as Boundary Lake crude oil from British Columbia, Canada, fed at a flow rate of 1.39 Kg/sec. d, and at a temperature of 25°C. The feed pressure was between 1.5 MPa and 2.0 MPa. The volume of crude oil used in each test was 7.0 liters having a mean viscosity at 25°C of 8.5 CPS.

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TABLE IX

MEMBRANE	MEMBRANES IN SERIES FLOW										
	INITIAL FEED	1U	2V	3V	4V	5V	6U	7U	8V	9V	FINAL FEED
PRESSURE, MPA		2.45	2.36	2.32	2.27	2.23	2.18	2.14	2.09	2.05	
FLUX, KG/MP.D		23.70	6.80	5.00	25.30	45.10	87.80	80.40	65.20	46.50	
VISCOSITY, CPS	10.06	3.04	3.38	3.41	3.02	3.38	3.05	3.22	3.65	5.08	11.28
VARIATION, %		71.50	68.30	68.00	71.70	68.30	71.40	69.80	65.80	52.39	
SULPHUR, %	0.80	0.47	0.52	0.53	0.47	0.49	0.49	0.48	0.50	0.50	0.83
SEPARATION, %		42.30	36.20	35.00	42.30	39.90	41.10	38.70	38.70	23.93	
VANADIUM, PPM	38.00	1.10	2.00	3.90	0.90	1.60	1.00	0.80	3.30	13.00	40.00
SEPARATION, %		97.20	94.90	90.00	97.70	95.90	97.40	97.90	91.50	66.67	
NICKEL, PPM	12.00	0.50	0.50	1.00	0.50	0.50	0.50	0.50	0.90	3.70	12.00
SEPARATION, %		95.80	95.80	91.70	95.80	95.80	95.80	95.80	92.50	69.17	
NITROGEN, G/L	9.60	3.32	3.59				3.01		3.62		9.60
SEPARATION, %		65.50	62.60				68.60		62.30		
Wt. average Molecular Wt.	553	318	338	367	327	346	327	340	377	433	592



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In the following Table X the feed was the Boundary Lake retentate from the test of the same designation in Table IX, which was the remaining concentrated 57% by volume of the feed for Table IX.

In Table X the flow rate of the feed for each test was 0.173 Kg/second, and at a temperature of 35°C. The feed pressure was between 2.0 MPa and 2.5 MPa. The volume of the oil used in each test was 4.0 liters having a mean viscosity at 35°C of 17.5 CPS.

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TABLE X

MEMBRANE	MEMBRANES IN SERIES FLOW									
	INITIAL FEED	1U	2V	3V	4V	5V	6U	7U	8V	FINAL FEED
PRESSURE, HPA		2.45	2.36	2.27	2.23	2.18	2.14	2.09	2.05	
FLUX, KG/MP.D		18.30	5.00	19.50	33.60	62.70	59.60	44.90	32.10	
VISCOSITY, CPS	24.34	4.86	5.20	5.17	5.06	4.96	5.39	6.65	8.68	29.84
VARIATION, %		82.10	80.80	80.80	81.30	81.70	80.10	75.50	67.96	
SULPHUR, %	0.92	0.54	0.54	0.58	0.52	0.51	0.56	0.61	0.70	0.95
SEPARATION, %		42.20	42.20	38.00	44.40	45.50	40.10	34.80	25.13	
VANADIUM, PPM	54.00	1.30	1.70	1.10	2.10	1.60	1.70	10.00	24.00	55.00
SEPARATION, %		97.60	96.90	98.00	96.10	97.10	96.90	81.70	55.96	
NICKEL, PPM	17.00	0.50	0.50	0.50	0.50	0.50	0.70	3.30	7.50	13.00
SEPARATION, %		97.10	97.10	97.10	97.10	97.10	96.00	81.10	57.14	
NITROGEN, G/L	12.56	1.82	3.97			3.62		5.35		12.56
SEPARATION, %		69.60	68.40			71.20		57.40		
Wt. average Molecular Wt.	661	356	387	377	364	357	364	440	496	638

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In the following Table XI the feed was a Canadian pipeline blend of crude oils, of unknown origin, fed at a flow rate of 0.210 Kg/second, and at a temperature of 30°C. The feed pressure for each test was between 2.0 MPa and 2.5 MPa. The volume of the crude oil used in each test was 9.5 liters having a mean viscosity at 30°C of 5.1 CPS.

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TABLE XI

MEMBRANE	MEMBRANES IN SERIES FLOW										
	INITIAL FEED	1U	2V	3V	4V	5V	6U	7U	8V	9V	FINAL FEED
PRESSURE, MPA		2.45	2.34	2.32	2.27	2.23	2.18	2.14	2.09	2.05	
FLUX, KG/M <sup>2</sup> .D		31.30	8.70	7.20	34.80	61.30	133.70	123.90	70.90	46.30	
VISCOSITY, CFS	10.29	3.47	3.85	4.09	3.74	3.77	3.72	3.82	3.87	3.83	12.27
VARIATION, %		69.20	65.90	63.70	66.80	66.60	67.00	66.10	65.70	65.87	
H <sub>2</sub> O	414.00	244.00	259.00	266.00	254.00	254.00	251.00	254.00	259.00	256.00	426.00
VARIATION, %		41.90	38.30	36.70	39.50	39.50	40.20	38.50	39.30	39.05	
SULPHUR, %	0.58	0.36	0.36	0.38	0.35	0.36	0.35	0.36	0.35	0.36	0.62
SEPARATION, %		40.00	40.00	36.70	41.70	40.00	41.70	40.00	41.70	40.00	
VANADIUM, PPM	2.50	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	3.20
SEPARATION, %		29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.82	
NICKEL, PPM	3.40	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	3.70
SEPARATION, %		85.90	85.90	85.90	85.90	85.90	85.90	85.90	85.90	85.92	
CHROMIUM, PPM	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
NITROGEN, G/L	6.38	1.76	2.04				1.84		1.99		6.38
SEPARATION, %		72.50	68.10				71.20		68.90		

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In the following Table XII the feed was the pipeline blend crude  
oil's retentate from the test of the same designation in Table XI,  
representing the remaining concentrated 47% of the initial feed of Table  
XI.

5            In Table XII the flow rate of the feed for each test was 0.132  
Kg/second, and at a temperature of 30°C. The feed pressure was between  
2.0 MPa and 2.5 MPa. The volume of the oil used in each test was 5.0  
liters having a mean viscosity at 30°C of 15.4 CPS.

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TABLE XII

MEMBRANE	INITIAL FEED	MEMBRANES IN SERIES FLOW				
		1V	2V	3V	4V	FINAL FEED
PRESSURE, MPa		2.45	2.27	2.18	2.09	
FLUX, KG/M <sup>2</sup> .D		15.90	19.70	63.80	41.80	
VISCOSITY, CPS	22.88	4.46	5.06	5.60	5.92	22.88
VARIATION, %		80.50	77.90	75.50	74.10	
MW						
VARIATION, %	465.00	259.00	269.00	270.00	285.00	481.00
		45.20	43.10	42.90	39.70	
SULPHUR, %		0.35	0.35	0.36	0.37	0.65
SEPARATION, %	0.63	45.30	45.30	43.70	42.20	
VANADIC, PPM						
SEPARATION, %	3.80	0.60	0.60	0.60	0.60	4.50
		85.50	85.50	85.50	85.50	
NICKEL, PPM						
SEPARATION, %	6.00	0.50	0.50	0.50	0.50	6.80
		92.20	92.20	92.20	92.20	
NITROGEN, G/L						
SEPARATION, %	8.14	2.01		2.11	2.61	8.14
		75.30		74.10	67.90	

The following Tables XIII to XXI give results of tests carried out on various tar sands bitumen to verify the present invention for different membranes.

In the following Table XIII, the feed was Athabasca Tar Sands bitumen obtained from the Solvent Extraction Spherical Agglomeration (SESA) process. The flow on the retentate side of the membranes was 3 liters/minute at a pressure of 9 bars and at 20°C.

For comparison, the analysis of oil upgraded by the conventional method of solvent extraction and centrifugation called Maltenes is shown.

It is evident that the conventional method for removing asphaltenes is not effective in removing nitrogen, sulphur, nickel and vanadium which are the most important contaminants.

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TABLE XIII

## MEMBRANE PROCESS

Sample	Asphaltenes % of Bitumen	Weight Avg. MW	Nitrogen %	NI ppm	V ppm	Cr ppm	Fe ppm	Cu ppm	S %	Flux*
Initial feed - similar to Bitumen %	15	14308	0.16	60	170	12	100	2.3	3.6	**
Concentrate	20	41600	0.23	82	250	14	190	3.0	4.0	**
Membranes										
2V	0	489	0	12	17	9	40	0.3	2.3	44
1U	0	493	0	12	18	7	30	0.2	2.5	60
3U	0	623	0	16	33	9	40	0.3	3.0	100
3U	0	508	0	13	24	9	40	0.3	2.5	30
1U	0	567	0	13	22	8	35	0.3	2.4	70
PA3	0	635	0	13	26	6	30	0.2	3.0	24

PAN is a polyacrylonitrile membrane

## CONVENTIONAL SOLVENT EXTRACTION PROCESS USING PENTANES AND CENTRIFUGATION

Bitumen A	15	14000	0.2	31	69	34	260	76	3.7	
Maltenes A by sol- vent extraction	0	1115	0.21	39	78	4.8	20	0.4	3.5	

## GESA Feed

20% Oil .8W<sub>2</sub>O 2% Solids 77% Naphtha\* Flux in  $\text{kg/m}^2/\text{day}$ \*\* 3  $\text{L/min}$  feed flow



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In the following Table XIV, the feed was Lloyd Primary Bitumen fed at a flow rate of 0.31 Kg/s at a temperature of 38°C and a pressure between 2.0 MPa and 2.6 MPa on the retentate side of the membranes. The volume of oil used was 8.5 liters having a mean viscosity of 85 CPS at

5 38°C.

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TABLE XIV

MEMBRANE	MEMBRANES IN SERIES FLOW										
	INITIAL FEED	1U	2V	3V	4V	5V	6U	7U	8V	9V	FINAL FEED
PRESSURE, MDA		2.55	2.44	2.38	2.33	2.27	2.22	2.16	2.11	2.05	
FLUX, KG/M <sub>2</sub> ·D		12.80	2.70	5.40	10.00	18.50	35.20	28.50	19.20	13.50	
VISCOSITY, CTS	68.60	4.20		5.96	4.89	4.97	4.92	5.10	6.26	6.51	102.00
VARIATION, %		95.10		93.00	94.30	94.20	94.20	94.00	92.70	92.37	
NH <sub>3</sub>	843.00	390.00		444.00	420.00	432.00	423.00	440.00	474.00	482.00	843.00
VARIATION, %		53.70		47.30	50.20	48.80	49.80	47.80	43.80	42.82	
SULFUR, %	3.39	1.71	2.01	1.88	1.85	2.05	1.79	1.86	1.97	1.99	3.32
SEPARATION, %		49.00	40.10	44.00	44.90	38.90	46.60	44.60	41.30	40.69	
VANADILIN, PPM	62.00	1.10	3.60	3.10	1.80	2.00	1.70	1.80	4.80	9.90	64.00
SEPARATION, %		98.30	94.30	95.10	97.10	96.80	97.30	97.10	92.40	84.29	
NICKEL, PPM	29.00	1.00	2.00	1.70	1.00	1.60	0.90	1.30	2.70	4.60	29.00
SEPARATION, %		96.60	93.10	94.10	96.60	94.50	96.90	95.50	90.70	84.14	
NITROGEN, G/L	13.08	2.41	3.44				2.51		3.24		13.08
SEPARATION, %		81.6	73.7				80.80		75.20		

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In the following Table XV, the feed was Lloyd Primary Bitumen from Table XIV after removal of 4.5 liters of permeate fed at a flow rate of 0.028 Kg/s at a temperature of 42°C and a pressure between 2.0 MPa and 3.4 MPa on the retentate side of the membranes. The volume of oil used was 4 liters having a mean viscosity of 295 CPS at 42°C.

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TABLE XV

MEMBRANE	MEMBRANES IN SERIES FLOW										FINAL FEED
	INITIAL FEED	1U	2V	3V	4V	5V	6U	7U	8V	9V	
PRESSURE, MPA		3.27	3.02	2.89	2.76	2.64	2.51	2.38	2.25	2.13	
FLUX, $\text{KG/M}^2 \cdot \text{H}$		10.30	9.70	48.20	10.80	15.70	20.30	15.50	14.80	12.70	
VISCOSITY, CPS	276.00	5.66	6.23	7.38	8.04	8.95	7.91	9.25	9.71	11.77	314.00
VARIATION, %		98.10	97.90	97.50	97.30	97.00	97.30	96.90	96.70	96.01	
PW VARIATION, %	923.00	396.00	405.00	423.00	449.00	468.00	461.00	481.00	501.00	512.00	914.00
		56.90	55.90	53.90	51.10	49.00	49.80	47.60	45.50	44.26	
SULFUR, % SEPARATION, %	3.75	1.79	1.82	1.89	1.85	1.92	1.92	1.97	2.03	2.20	3.90
		53.20	52.40	50.60	51.60	59.80	49.80	48.50	46.40	42.49	
VANADIUM, PPM SEPARATION, %	103.00	2.60	1.50	2.70	2.90	2.30	2.20	3.40	4.50	7.00	107.00
		97.50	98.60	97.40	97.20	97.80	97.90	96.80	95.70	93.33	
NICKEL, PPM SEPARATION, %	46.00	1.10	1.20	1.40	1.60	1.90	1.80	2.00	2.60	3.70	50.00
		97.70	97.50	97.10	96.70	96.00	96.30	95.80	94.60	92.29	
NITROGEN, G/L SEPARATION, %	10.96	2.64	2.52				3.04		3.64		10.96
		75.90	77.10				72.30		66.80		

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In the following Table XVI, the feed was Cold Lake Bitumen  
diluted by 34% naphtha, fed at a flow rate of 0.126 Kg/s at a temperature  
of 46°C and a pressure between 2.0 MPa to 2.5 MPa on the retentate side  
of the membranes. The volume of oil used was 5.5 liters having a mean  
5 viscosity of 27.2 CPS at 46°C.

In Figure 3 there is shown a graph of the molecular weight  
distribution of the Cold Lake Bitumen test designated U6 in Table XVI  
obtained by the previously mentioned high performance liquid  
chromatograph. In Figure 3 the molecular weight M is plotted against  
10 elution volume. The line ----- is for the feed hydrocarbon which has a  
weight average molecular weight of 814 and line — is for the permeate  
which has a weight average molecular weight of about 400.

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TABLE XVI

MEMBRANE	MEMBRANES IN SERIES FLOW										
	INITIAL FEED	1U	2V	3V	4V	5V	6U	7U	8V	9V	FINAL FEED
PRESSURE, MPA		2.45	2.36	2.32	2.27	2.23	2.18	2.14	2.09	2.05	
FLUX, KG/M <sup>2</sup> .D		41.60	9.90	18.70	27.10	54.80	128.20	113.20	60.90	40.20	
VISCOSITY, CTS	22.00	0.00	1.31	1.45	1.63	1.54	1.56	1.70	1.72	1.76	32.40
VARIATION, %		100.00	95.10	94.70	94.00	94.30	94.30	93.50	93.70	93.53	
NH <sub>3</sub>											
VARIATION, %	814.00	373.00	393.00	394.60	402.00	408.00	399.00	415.00	442.00	452.00	838.00
		54.80	52.40	52.30	51.30	50.60	51.70	59.80	46.50	45.28	
SULFUR, %	3.30	1.45	1.34	1.41	1.47	1.46	1.46	1.46	1.52	1.58	3.32
SEPARATION, %		55.00	59.50	57.40	55.60	55.90	55.90	54.10	54.10	52.27	
VALUOLIN, PPM	102.00	2.10	2.60	2.80	2.60	2.90	1.80	2.20	4.00	8.60	108.00
SEPARATION, %		98.00	97.50	97.30	97.50	97.20	98.30	97.90	96.20	91.81	
NICKEL, PPM	34.00	1.20	1.20	1.60	1.40	1.50	1.10	1.40	2.20	3.20	35.00
SEPARATION, %		96.50	96.50	95.40	95.90	95.70	96.80	95.90	93.60	90.72	
NITROGEN, G/L	13.87	1.81	2.14				2.01		2.34		13.87
SEPARATION, %		87.00	84.60				85.50		83.20		

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In the following Table XVII, the feed was Cold Lake Bitumen from the test in Table XVI after removal of 2.5 liters of permeate. The feed was introduced at a flow rate of 0.985 Kg/s at a temperature of 45°C and a pressure between 2.0 MPa to 3.0 MPa on the retentate side of the 5 membranes. The volume of oil used was 3 liters having a mean viscosity of 89.6 CPS at 45°C.

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TABLE XVII

MEMBRANE	MEMBRANES IN SERIES FLOW										
	INITIAL FEED	1V	2V	3V	4V	5V	6V	7V	8V	9V	FINAL FEED
PRESSURE, MPA		2.91	2.73	2.64	2.55	2.45	2.36	2.27	2.18	2.09	
FLUX, KG/M <sup>2</sup> .D		31.60	14.90	20.50	21.60	46.60	77.10	63.00	42.30	33.60	
VISCOSITY, CPS	74.90	1.72	2.12	1.90	2.05	2.06	2.11	2.25	2.65	3.55	104.30
VARIATION, %		98.10	97.60	97.80	97.70	97.70	97.60	97.50	97.00	96.04	
MW	868.00	412.00	401.00	425.00	418.00	425.00	436.00	438.00	500.00	561.00	891.00
VARIATION, %		53.20	54.40	51.70	52.50	51.70	50.40	50.20	43.10	36.21	
SULPHUR, %	3.64	1.50	1.63	1.59	1.64	1.65	1.65	1.72	1.84	2.12	3.63
SEPARATION, %		58.70	55.20	56.30	54.90	54.60	54.60	52.70	49.40	41.58	
VANADIUM, PPM	124.00	2.80	4.10	3.10	3.30	3.50	3.20	3.80	11.00	30.00	125.00
SEPARATION, %		97.80	96.70	97.50	97.30	96.20	97.40	96.90	91.20	75.90	
NICKEL, PPM	41.00	1.20	1.90	1.60	2.20	2.10	1.80	2.20	4.30	11.00	41.00
SEPARATION, %		97.10	95.40	95.60	94.60	94.90	95.60	94.60	89.50	73.17	
NITROGEN, G/L	16.78	2.44	2.74				2.81		3.52		16.78
SEPARATION, %		85.50	83.70				83.20		79.00		



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In the following Table XVIII the feed was Carbonate Trend  
Bitumen diluted by 41% with naphtha and fed at a flow rate of 0.034 Kg/s  
at a temperature of 25°C and a pressure between 2.4 MPa to 2.9 MPa on the  
retentate side of the membranes. The volume of oil used was 8 liters  
5 having a mean viscosity of 80.8 CPS at 25°C.

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TABLE XVIII

MEMBRANE	MEMBRANES IN SERIES FLOW										
	INITIAL FEED	1U	2V	3V	4V	5V	6U	7U	8V	9V	FINAL FEED
PRESSURE, MPa		2.85	2.76	2.72	2.67	2.63	2.58	2.54	2.49	2.45	
FLUX, $\text{KG/M}^2 \cdot \text{D}$		32.70	13.50	25.20	32.60	50.30	48.10	64.70	46.60	44.10	
VISCOSITY, CTS	57.10	0.97	0.93	0.88	0.97	1.00	1.00	1.05	1.03	1.01	104.50
VARIATION, %		98.90	98.80	98.90	98.80	98.80	99.80	98.70	98.70	98.75	
AV	844.00	361.00	365.00	370.00	390.00	404.00	396.00	410.00	408.00	407.00	850.00
VARIATION, %		57.40	56.90	56.10	54.00	52.30	53.20	51.60	51.80	51.95	
SULFUR, %	3.77	1.04	1.33	1.04	1.20	1.24	1.22	1.32	1.30	1.24	3.98
SEPARATION, %		73.20	65.90	73.20	69.00	68.00	68.50	65.90	66.50	68.00	
VANADIUM, PPM	114.00	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	3.00	118.00
SEPARATION, %		97.80	97.80	97.80	97.80	97.80	97.80	97.80	97.80	97.41	
NICKEL, PPM	35.00	0.50	0.60	0.50	0.60	0.60	0.60	1.00	0.80	0.80	36.00
SEPARATION, %		98.60	98.30	98.60	98.30	98.30	98.30	97.20	97.70	97.75	
NITRILIN, G/L	16.23	1.66	1.61				1.71		1.81		16.23
SEPARATION, %		89.80	90.10				89.50		88.90		

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In the following Table XIX the feed was Carbonate Treated Bitumen from the test described in Table XVIII after removal of 50% of the feed as permeate. The now concentrated feed was fed at a flow rate of 0.02 Kg/s at a temperature of 35°C and a pressure between 2.0 MPa to 3.5 MPa on the retentate side of the membranes. The volume of oil used was 4 liters having a mean viscosity of 392.5 CPS at 35°C.

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TABLE XIX

MEMBRANE	MEMBRANES IN SERIES FLOW										
	INITIAL FEED	1U	2V	3V	4V	5V	6U	7U	8V	9V	FINAL FEED
PRESSURE, MPA		3.36	3.09	2.95	2.82	2.68	2.55	2.41	2.27	2.14	
FLUX, KG/M <sup>2</sup> .D		16.70	6.10	11.60	12.90	19.50	24.90	17.20	17.40	16.50	
VISCOSITY, CPS	290.10	1.18	1.25	1.32	1.56	1.64	0.00	1.81	1.88	1.93	576.00
VARIATION, %		99.70	99.70	99.70	99.60	99.60	100.00	99.50	99.50	99.51	
MW	879.00	370.00	409.00	396.00	425.00	450.00	53.00	465.00	470.00	469.00	900.00
VARIATION, %		58.40	54.00	55.20	52.20	49.40	49.10	47.70	47.20	47.27	
SULPHUR, %	4.29	1.42	1.96	1.47	1.59	1.92	1.98	1.91	2.00	1.87	4.67
SEPARATION, %		68.70	56.30	67.20	64.50	57.10	55.80	57.40	55.40	58.26	
VANADIUM, PPM	133.00	2.50	5.30	2.50	3.10	1.50	3.40	3.90	5.30	5.00	136.00
SEPARATION, %		98.10	96.10	98.10	97.70	97.40	97.50	97.10	96.10	96.28	
NICKEL, PPM	41.00	0.90	1.80	1.20	1.60	2.00	1.80	1.80	2.50	2.10	41.00
SEPARATION, %		97.80	95.60	97.10	96.10	95.10	95.60	95.60	93.90	94.88	
WATER, G/G	13.08	2.30	2.10				2.54		2.81		13.08
SEPARATION, %		82.30	83.90				80.60		78.50		

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In the following Table XX the feed was Athabasca Bitumen from the hot water extraction process with a dilution of 37% with naphtha fed at a flow rate of 0.1 Kg/s at a temperature of 35°C and a pressure flow between 2.0 MPa and 2.5 MPa on the retentate side of the membranes. The volume of oil used was 6.5 liters having a mean viscosity of 21.9 CPS at 35°C.

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TABLE XX

MEMBRANE	MEMBRANES IN SERIES FLOW										
	INITIAL FEED	1U	2V	3V	4V	5V	6U	7U	8V	9V	FINAL FEED
PRESSURE, MPa		2.45	2.30	2.32	2.27	2.25	2.18	2.14	2.09	2.05	
FLUX, $\text{KG/M}^2 \cdot \text{D}$		62.80	17.00	15.40	46.20	109.30	161.30	133.90	113.00	86.50	
VISCOSITY, CFS	19.20	1.12	1.22	1.21	1.23	1.32	1.32	1.37	1.42	1.35	24.60
VARIATION, %		94.90	94.40	94.50	94.00	94.00	94.00	93.70	93.50	93.84	
SW	797.00	400.00	416.00	417.00	423.00	443.00	443.00	451.00	467.00	451.00	807.00
VARIATION, %		50.10	48.10	48.00	47.30	44.80	44.80	43.80	41.80	41.77	
SULFUR, %	3.24	1.29	1.12	1.50	1.32	1.50	1.37	1.41	1.48	1.45	3.32
SEPARATION, %		60.70	52.80	54.30	59.80	54.30	58.20	57.00	54.90	55.79	
VANADIUM, PPM	99.00	1.80	1.80	2.10	1.80	2.30	1.80	1.80	3.60	2.70	105.00
SEPARATION, %		98.20	98.20	97.90	98.20	97.70	98.20	98.20	96.50	97.35	
NICKEL, PPM	32.00	1.00	1.00	1.00	1.00	1.40	1.60	1.20	1.80	1.60	33.00
SEPARATION, %		96.90	96.90	96.90	96.90	95.70	96.90	96.90	94.50	95.08	
NITROGEN, G/L	14.22	1.99	4.42				2.24		2.54		14.22
SEPARATION, %		86.00	68.90				84.30		82.20		

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In the following Table XXI the feed was Athabasca Bitumen concentrate from the test of Table XX after removal of 3 liters of, permeate, fed at a flow rate of 0.025 Kg/s at a temperature of 34°C and a pressure flow between 2.0 MPa and 2.7 MPa on the retentate side of the  
5 membranes. The volume of oil used was 3.5 liters having a mean viscosity of 122.8 CPS at 34°C.

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TABLE XXI

MEMBRANE	MEMBRANES IN SERIES FLOW										
	INITIAL FEED	1U	2V	3V	4V	5V	6U	7U	8V	9V	FINAL FEED
PRESSURE, MPA		2.64	2.51	2.45	2.38	2.32	2.25	2.19	2.13	2.06	
FLUX, KG/M <sup>2</sup> .D		30.00	5.80	5.50	8.30	25.50	40.30	28.60	24.40	21.50	
VISCOSITY, CFS	95.14	1.60	0.00	1.71	1.94	2.06	2.09	2.26	2.19	2.12	
VARIATION, %		99.40	100.00	99.40	99.30	99.30	99.30	99.20	99.20	99.24	463.00
MW	894.00	438.00	453.00	442.08	462.00	486.00	466.00	477.00	479.00	467.00	888.00
VARIATION, %		50.80	49.20	50.40	48.10	45.50	47.70	46.50	46.20	47.59	
SULPHUR, %	3.82	1.54	1.87	1.78	1.67	1.76	1.75	2.02	1.82	2.11	3.94
SEPARATION, %		60.30	51.80	54.10	57.00	54.60	54.90	47.90	53.10	45.62	
VANADIUM, PPM	124.00	2.20	3.00	3.50	1.80	3.30	2.40	4.40	4.10	4.10	128.00
SEPARATION, %		98.30	97.60	97.20	98.60	97.40	98.10	96.50	96.70	96.75	
NICKEL, PPM	39.00	1.30	1.20	1.80	1.80	2.00	1.80	2.30	2.20	2.30	40.00
SEPARATION, %		96.70	97.00	95.40	95.40	94.90	95.40	94.20	94.40	94.18	
NITROGEN, G/L	18.99	2.79	2.89				3.01		3.39		18.99
SEPARATION, %		85.30	84.80				84.10		82.10		



The tests showed that when the microporous structure provided the outer layer on the retentate side with a molecular weight cut off greater than about 20,000 > membrane 9V, when measured in an aqueous medium, the microporous structure was more susceptible to plugging giving lower separation factors for the constituents and lower permeate fluxes.

The test results also indicated that using feeds having higher viscosities than those given in the Tables would give larger pressure drops with the equipment used on the retentate side of the membrane, causing more difficult pumping of hydrocarbon past the membrane which in turn would give lower permeation rates, and so the viscosities would have to be decreased for higher recoveries of the upgraded oil. The viscosity may be reduced by heating the oil or by adding a recoverable solvent, such as naphtha or hydrocarbon concentrates, such as those obtained from natural gas, provided that they are mainly aliphatic in nature. Higher viscosities could be accommodated by equipment with larger spacings on the retentate side of the membrane and by the use of larger pipe sizes in the construction of the equipment.

It was also evident from the tests that a retentate obtained from a fossil derived hydrocarbon liquid by the present invention may be enriched with at least one inorganic substance selected from groups IIA, IVA, VA, VIA, VIIA, VIIIA, IB, IIB, IIIB, IVB, VB and VIB of the Periodic Table as specified by the International Union of Pure and Applied Chemistry. Important inorganic substances included in this list and demonstrated to be separable in the previous examples are boron, nickel, vanadium, chromium, copper, aluminum, titanium, zinc, lead, iron,

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nitrogen, silicon, phosphorus, magnesium, calcium and sulphur, which were chosen to act as examples and are not meant to limit the present invention to these elements.

In the case of oil from oil shale or bitumen from tar sands,  
5 inorganic substances such as polyaromatic hydrocarbons, e.g. asphaltenes gums and waxes, may also be retained in the retentate obtained by the present invention.

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CLAIMS

1. A method of removing substances from fossil derived, hydrocarbon liquid, comprising passing the fossil derived hydrocarbon liquid as a feed containing at least one substance selected from the group consisting of higher molecular fractions thereof and inorganic substances and having a viscosity of less than about 600 centipoise, across a high pressure side of a microporous membrane, at pressure differential in the range of about one atmosphere to about 100 atmospheres (i.e. 0.1 to 10.0 MPa), at least an outer layer of the membrane, on the high pressure side thereof, being of at least one lyophilic, hydrocarbon liquid stable, organic, polymeric material, and having a microporous structure that provides the said at least an outer layer with a molecular weight cut off of less than about 20,000, when measured in an aqueous medium, and less than 4,000, when measured in oil, so that oil depleted in the said at least one substance permeates the membrane leaving liquid hydrocarbon enriched in the said at least one substance as a retentate on the high pressure side of the membrane.

2. A method according to claim 1, wherein the hydrocarbon liquid feed contains asphaltenes and the permeate is essentially asphaltene free.

3. A method according to claim 1, wherein the viscosity of the hydrocarbon liquid feed is reduced to less than about the said 600 centipoise by heating the hydrocarbon liquid.

CLAIMS (cont.)

4. A method according to claim 1, wherein the viscosity of the hydrocarbon liquid feed is reduced to less than about the said 600 centipoise by diluting the hydrocarbon liquid feed with a solvent thereof.
5. A method according to claim 1, wherein the retentate is enriched with at least one inorganic substance selected from the group consisting of nickel, vanadium, chromium, copper, aluminum, boron, titanium, zinc, lead, iron, nitrogen, silicon, phosphorus, magnesium, calcium and sulphur present in the hydrocarbon liquid.
6. A method according to claim 1, wherein the viscosity of the hydrocarbon liquid permeate is less than about 50% of that of the hydro-carbon liquid feed.
7. A method according to claim 1, wherein the said outer layer is of at least one material selected from the group consisting of polysulfones, polyacrylonitriles, polyamides and polyvinylidene fluoride.
8. A method according to claim 1, wherein the hydrocarbon liquid feed is passed across the retentate side of the membrane with the hydrocarbon liquid feed having a viscosity of less than about 400 centipoise, and the microporous structure of the said at least outer layer provides that layer with a molecular weight cut off of less than about 10,000 in an aqueous medium.

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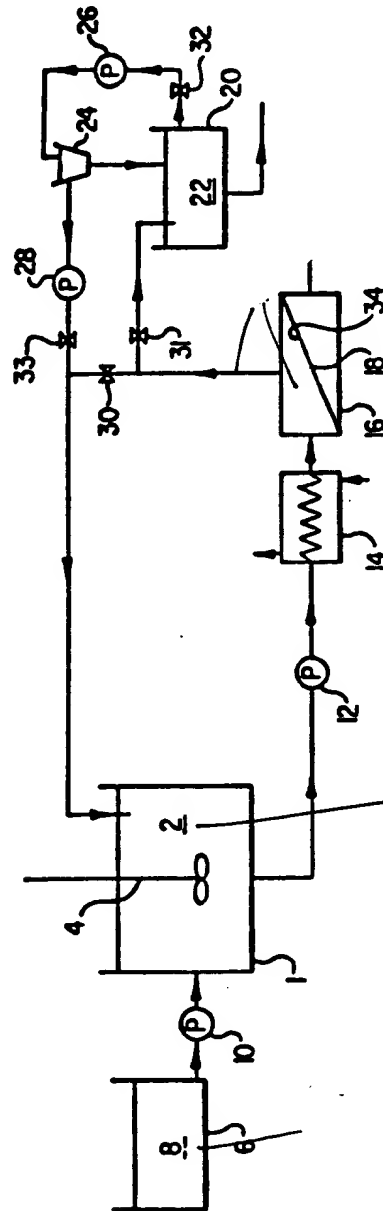
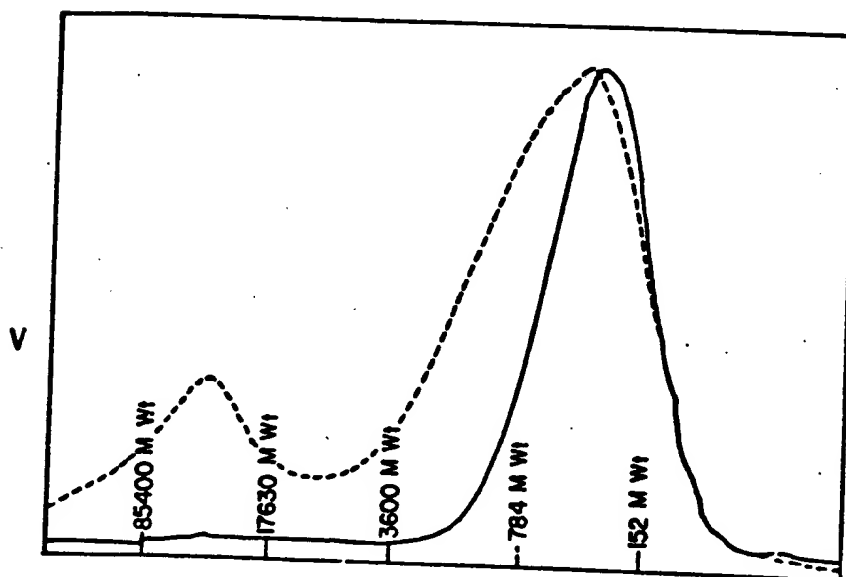
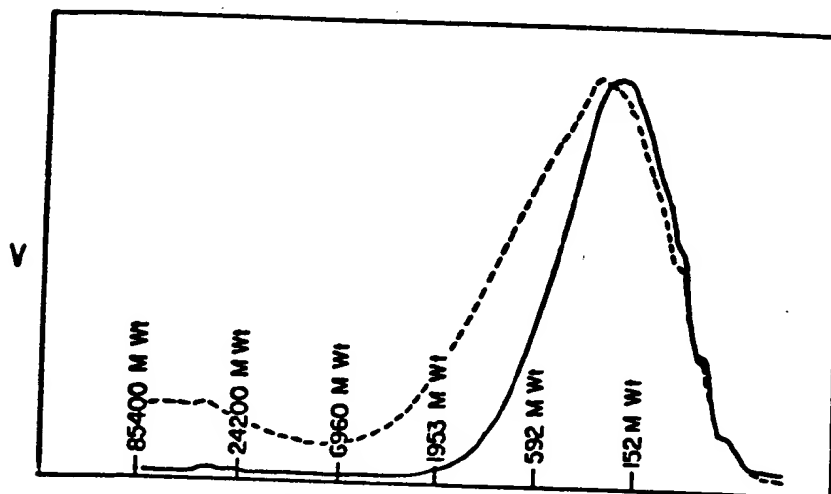


FIG. 1

Francis D. Lamm  
PATENT AGENT

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*Franklin D. Jones*  
PATENT AGENT